Seeds and Seedling Establishment of Wyoming Big Sagebrush

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Abstract

Success with Wyoming sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) depends on good seed vigor, and rapid seedling development. These characteristics are influenced by harvesting, processing, storing, and sowing. In this paper we discuss research findings related to those activities: (1) It appears that Wyoming big sagebrush growing on the western edge of the Great Plains might hold viable seed longer into the winter, and might have greater seed dormancy than do other habitat types. (2) Tests of debearder-processed seeds indicate the procedure does not degrade seed quality. (3) Sagebrush seeds in storage often show unexpected, and seemingly random viability losses. We need research to define the interactions of seed physiology and storage conditions and to predict seed shelf-life. (4) Temperature has a measurable influence on water absorption by sagebrush seeds, but the rate and extent of water absorption does not appear to influence germination or seedling vigor. (5) Moisture stress will affect germination and an increase in moisture stress from 0.00 to -0.50 MPa will result in approximately half of germinable seeds remaining ungerminated. (6) Heavy seeds germinate better. We recommend seed buyers select seed lots with less than 3500 seeds/g to obtain high-vigor seeds; also, that seed lots be monitored using inexpensive in-the-office tests of germination. (7) We recommend sagebrush seeding rates of 1000 seeds/m^2. Lower seeding rates reduce stand density but heavier rates do not give a corresponding density increase. High seeding rates are consistent with sagebrush ecology.

Introduction

The re-establishment of diverse, self-sustaining plant communities that include native shrubs is a prerequisite for bond release to mining companies extracting mineral resources in Wyoming (Federal Register 1996) and other western states. Shrub re-establishment in general, and sagebrush restoration in particular, have presented continuing challenges that only recently have met with some consistency and predictability. Where the 1986 Wyoming coal mining rules stated a **goal** of one shrub /m^2 on 10% of the affected area, the 1996 rule **requires** one shrub /m^2 on 20% of the affected area (Federal Register 1996, Booth et al. 1999). Success with sagebrush, perhaps more than with other native shrubs, depends on a properly prepared seedbed, good seed vigor, and rapid seedling development. Sagebrush seeds are influenced by harvesting, processing, storing, and sowing. In this paper we review some fundamentals for successfully seeding Wyoming big sagebrush.

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Big Sagebrush Seeds

Big sagebrush seeds are shiny achenes, about 2 mm long and enclosed in a papery pericarp that is often removed during seed cleaning (Booth et al. 1997). The pericarp can influence seed water uptake; although, differences in water uptake among naked and pericarp-covered achenes are small and probably not biologically significant (Bai et al. 1999). The achenes contain mucilaginous materials that may aid adhesion to the soil surface during radicle penetration (Walton et al. 1986). Achene endosperm is a membrane fused to the inner wall of the seed coat (Atwater 1980, Meyer, in press). The cotyledons are large, thickened and dominate the axis. Young and Young (1992) reported Wyoming big sagebrush has 3500-3800 seeds/g and Bai et al. (1997) reported 3100-4500 seeds/g for five Wyoming collections harvested in February. Most sagebrush seeds used in reclamation are collected from native stands where seed production and quality vary from site to site, reflecting ecotypical influences, and from year to year as a result of weather and parental condition. Seed quantity and quality varies, but reclamation continues. This, and the late seed-ripening dates mean that reclamation depends on seeds stored from previous year's harvests. Thus seed quality changes during storage, and the frustratingly short shelf-lives of some seed lots, are important revegetation issues.

Harvesting, Processing, and Storing Seeds

Sagebrush blooms in late summer and early fall and seeds mature October through December. Young and Young (1992) cautioned that seeds need to be harvested quickly after maturity to avoid losses and storm damage associated with the late season and Walton et al. (1986) report that viable seeds are dispersed during the first seven days after seed-ripening. Most sagebrush seed harvesting occurs in late fall or early winter, but significant amounts of Wyoming big sagebrush in Wyoming can be harvested in February (Bai et al. 1997), indicating ripe seeds are held longer than seven days and that dispersion is spread over a greater time period. Whether this is a characteristic of the subspecies, or a characteristic correlated to the more eastern part of sagebrush distribution is not known (see Meyer and Monsen 1992 for a discussion of habitat-correlated characteristics of sagebrush seeds).

Seed harvesting produces a mixture of seed stalks, flower parts, and seeds which is usually processed with debearders (a machine originally designed to remove the beard or awn from barley). Booth et al. (1997) found that debearder processing resulted in significant increases in the temperature and relative humidity of the material being processed (Fig. 1), but the transient (<10 min.) conditions had no effect on seed quality as measured by percent germination, germination rate, and seedling vigor. Even running a large load for 20 minutes did not damage seeds nor decrease quality factors. Debearders do remove the pericarp from a fraction of the seeds and the longer seeds are in the machine, the greater the percentage with pericarp removal (Fig. 2). However, pericarp removal had no effect on seed germination percentage or rate, nor was there any evidence that it affected seed shelf life (Booth et al. 1997).

Some Wyoming big sagebrush seed lots undergo costly, untimely decreases in germination percentage during storage. Bai et al. (1997) made five collections from Wyoming, stored them for 24 months at room temperature, and found that germination increased for one collection, decreased for two collections, and did not change for two collections. Shaw and Booth (1999) stored two lots of Idaho-collected Wyoming big sagebrush seeds for 15 months at -22°C and at room temperature, experienced significant reductions in germination percentage after six months regardless of storage

Fig. 1. Changes in temperature and relative humidity inside a debearder while processing Wyoming big sagebrush seeds (Booth et al. 1997).

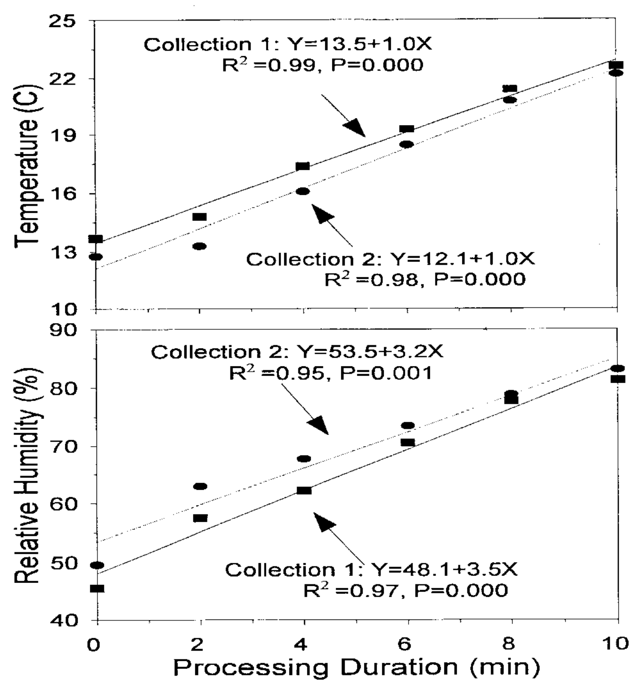
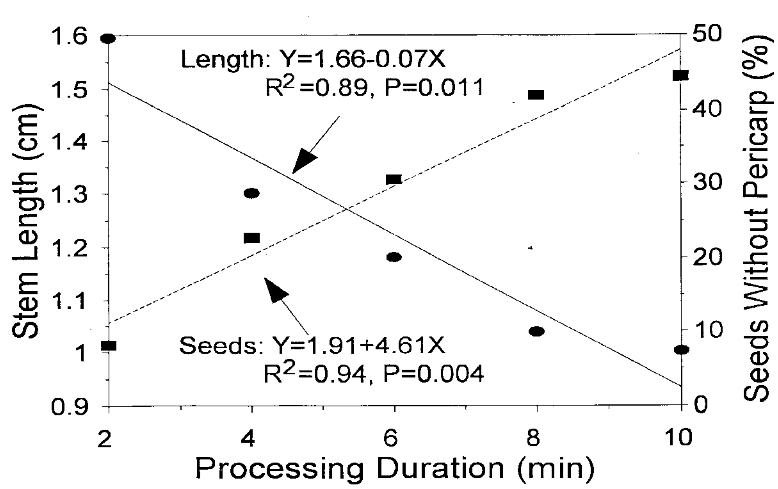


Fig. 2. Stem length and percent of Wyoming big sagebrush seed without pericarp after processing with a debearder (Booth et al. 1997). Stem-length change is a measure of the abrasive action of the debearder on stems contained in material collected at seed harvest.



conditions. After 15 months one protocol indicated cold storage preserved viability but the other protocol indicated decreased viability with no difference among storage conditions. Such results emphasize our need to understand environmental interactions with seed aging – particularly as it relates to accurate seed testing.

Dormancy and Germination Characteristics

Atwater (1980) has noted that seed dormancy in nonendospermic seeds is due to impermeable seed coats or to germination inhibitors contained within the seed. Sagebrush does not have impermeable seed coats and no germination inhibitors have been identified. However, Wyoming big sagebrush seed lots are known to contain some viable seeds that are not readily germinable after harvest (McDonough and Harniss 1974, Meyer and Monsen 1992, Bai et al. 1997, Booth et al. 1997). Meyer and Monsen (1992) reported that Wyoming big sagebrush seeds from 21 collections were largely nondormant when germinated at 15°C in light. The maximum percentage of dormant seeds in these collections was 11%. All of their collections were from west of the 110th meridian and whether or how the geographic range influenced their results is unknown. Booth et al. (1997) studied two commercial seed lots and found that germination percentage increased by 15 to 20% after 4.5 months of storage, indicating an afterripening effect. Afterripening is post-harvest embryo maturation measured as the time required for seeds to become germinable. True dormancy may also affect a fraction of Wyoming sagebrush seeds. Seeds collected from and sown in the Powder River Basin produced seedlings during four post-sowing growing seasons where annual photographs of plots were used to map and document the establishment and survival of sagebrush seedlings (Booth, D.T. unpublished data).The photographic data extrapolated to large areas imply two to seven thousand seedlings/ha may appear the fourth growing season after seeds are sown, thus distributing Wyoming big sagebrush emergence from a single seed lot through at least three years.

Water Relations and Germination

Seed germination and germination rate of Wyoming big sagebrush are limited by water stress,- similar to basin big sagebrush (Sabo et al. 1979, Walton et al. 1986) and fringed sagebrush (Bai et al. 1995). An increase in moisture stress from 0.00 to -0.50 MPa will result in approximately half of germinable seeds remaining ungerminated and those that do germinate will take twice as long as for seeds with no stress (Fig. 3).

Orthodox seeds like sagebrush are dispersed as desiccated micro-plants. How rehydration occurs, the rate, temperature, and extent, often has a lasting influence on germination and seedling performance (see Booth 1993). Managed rehydration, known as "seed priming," has enhanced field performance of a variety of agricultural seeds (Taylor and Harmon 1990). Bai et al. (1997) tested the interactions of temperature and time on seed water uptake of Wyoming big sagebrush under humid conditions. Significant moisture increases occurred after; 16 hours at 2°C, 4 hours at 5°C, and 2 hours at 10 and 15°C (Figure 4). Seed moisture content equilibrated with humidity and was highest under the 10°C regime. Surprisingly, no differences were detected in germination percentage, germination rate, or seedling vigor that could be related to moisture uptake. Neither did imbibition under wet (as contrasted to humid) conditions appear to have any significant influence on these processes. Thus, priming appears unlikely to enhance field performance of Wyoming big sagebrush.

Fig. 3. Predicted germination percentage (solid line at left) and rate (D50, solid line at right) with 95% confidence bands (dotted line) of Wyoming big sagebrush seeds with (filled circles) or without (open triangles) pericarp as a function of water potential (Bai et al. 1999). Symbols indicate actual values.

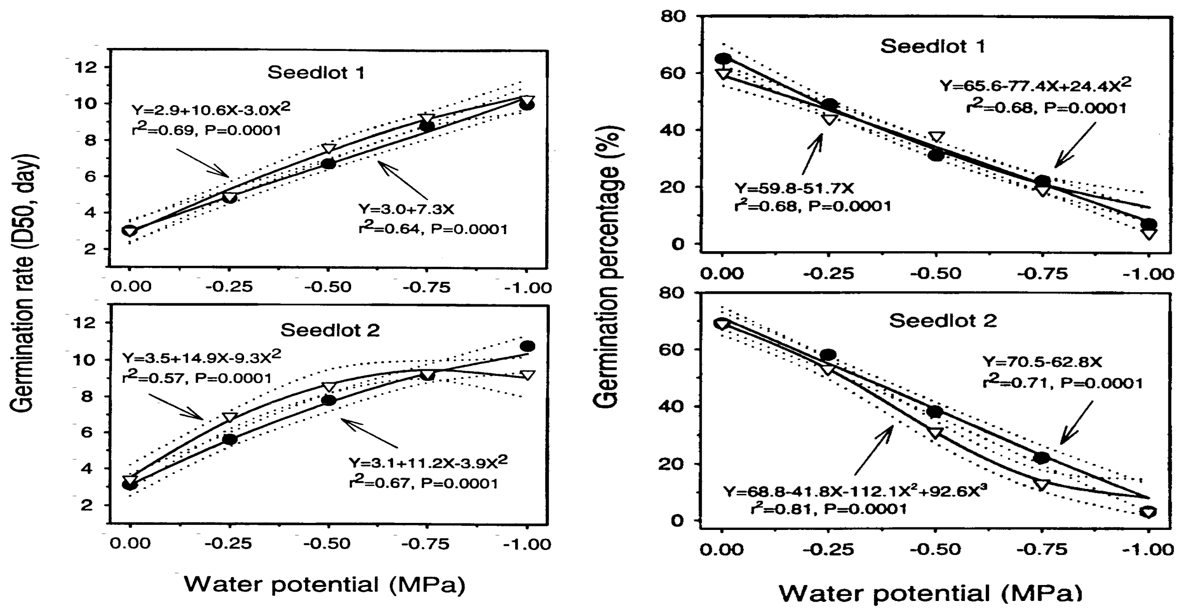
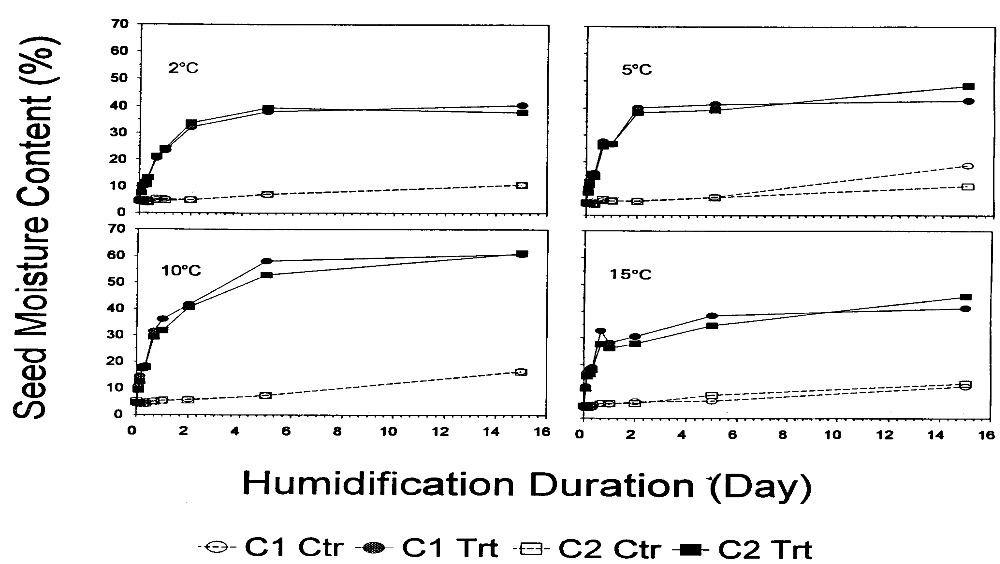


Fig. 4. Seed moisture content of humidified (Trt) and non-humidified (Ctr) Wyoming big sagebrush seeds at different temperatures and treatment durations (Bai et al. 1997).



Seed Size / Testing/ Seeding Rates

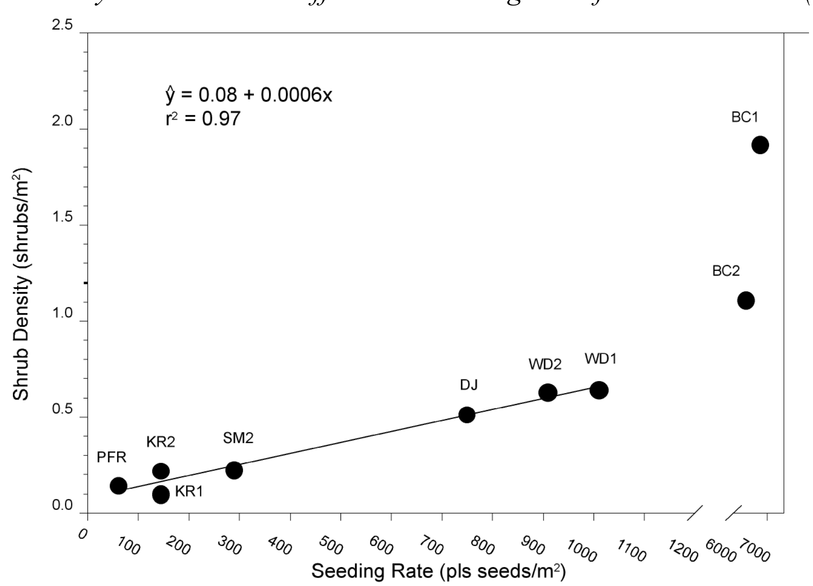
Heavy Wyoming big sagebrush seeds are likely to germinate more quickly and to a greater extent than lighter seeds (Bai et al. 1997). We advise sagebrush seed buyers to pay attention to seed weight and look for lots with less than 3500 seeds/g (remembering that heavier seeds mean fewer seeds per gram). Our selection of 3500 seeds/g is arbitrary and based only on the range in seed weight reported in this paper and our findings that the heavier seed lots performed better than light seed lots.

Seed testing must be an ongoing exercise for sagebrush and can be conducted in the office at low-cost. In addition, seed lots older than six months from harvest should always be evaluated within a month of sowing. [See Bai et al. 1997 for our method of testing Wyoming big sagebrush seeds.]

Germination and seedling establishment are rapid under optimum temperature and moisture conditions when seeds are physiologically ready. However, the co-incidence of germinable seeds and optimum conditions in the field is unpredictable and random and the source of episodic "pulses" in seedling recruitment (Lommasson 1948, Walton et al. 1986, Schuman et al. 1998, Booth et al. 1999). Numerous agronomic practices have been developed to enhance establishment and these are discussed elsewhere in these proceedings. Regardless of these practices, the variability of weather and biological systems make optimum field conditions hard to predict and unlikely to be arranged. Older reclaimed sites with sagebrush have been found to have a shrub density directly correlated to seeding rates up to 1000 seeds/m^2 (Figure 5)(Booth et al. (1999).

The sagebrush diaspore is simple in construction and functions. The reproductive strategy is small seed size, high seed numbers, and distribution near the mother plant (Walton et al. 1986). High seeding rates are therefore consistent with sagebrush ecology. As with other species "good management requires an understanding of ...specific seedbed ecologies and innovation in adapting methods of seed distribution and fixation that will complement ... diaspore functions most critical to seed success" (Booth 1987).

Fig. 5. Shrub density as influenced by the number of pure live seeds sown. The regression equation does not include data from the BC1 & 2 sites. Note the break in the x axis between 1200 and 6000 seeds/m^2. Letter symbols indicate different mines. Figure is from Booth et al. (1999)



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